TEST & ALIGNMENT PROCEDURES

for

160A & 260A Q Meters

BOONTON DIVISION
Hewlett-Packard Company

INDEX TO Q METER ARTICLES IN THE BRC NOTEBOOK

The following articles in the BRC Notebook supplement the information in this manual. Copies of the Notebook are available through your nearest Hewlett Packard Sales Office.

Most of the service information in the BRC Notebooks has largely been incorporated in this manual; the service articles are added here only for completeness.

	Article	BRC Notebook No.
Theory:	The Nature of Q	1
	Q Meter Comparison	2
	A Versatile Instrument - The Q Meter	4
	Circuit Effects on Q*	8
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Applications:	A Versatile Instrument - The Q Meter	4
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Note: A Manual of Radio Frequency Measurements, containing the basic measurement technique using Q Meters is available from your -hp- Sales Office for $2.50.

*Also includes "Correlation of 190A and 260A Q Meters on Overlapping Frequency Ranges.

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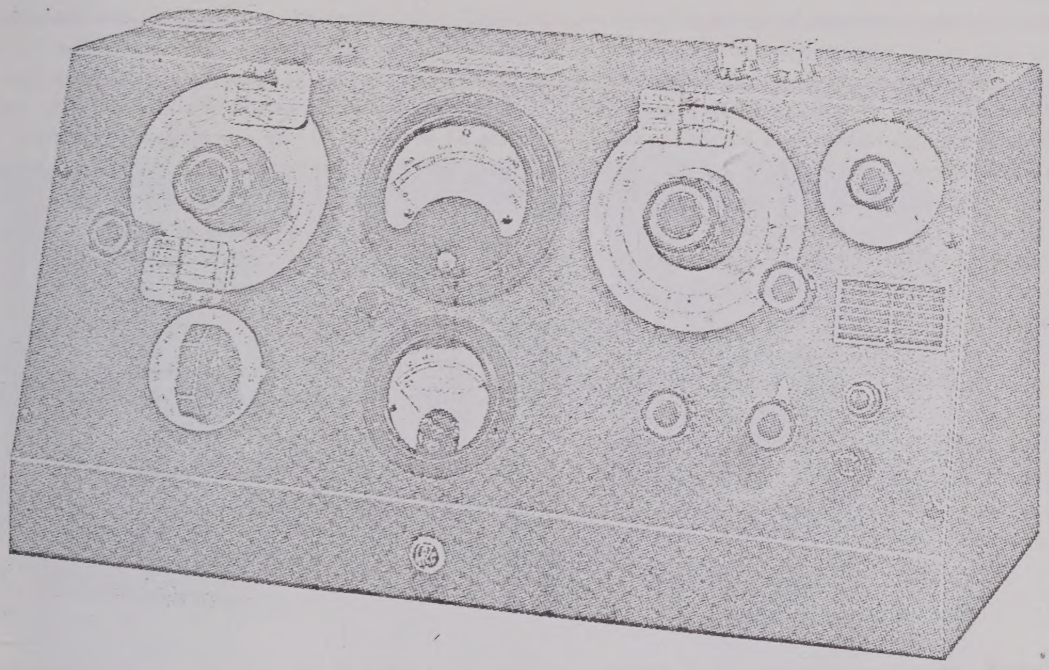
SECTION I

TECHNICAL DATA

AND

SPECIFICATIONS

Q METER TYPE 160-A



Frequency Range 50 KC-75 MC

OPERATING PRINCIPLE

The symbol Q is commonly used to designate the ratio of reactance to resistance of a coil ($Q=2\pi fL/R$) or of a condenser ($Q=1/2\pi fCR$). This factor is of fundamental significance in circuit design, since it is a "figure of merit" of the reactive elements. For example, the higher the value of Q the greater the selectivity and the amplification of a stage in which the reactors are used.

The Q of a simple resonant circuit may be measured by impressing a known voltage in series in the circuit and measuring the voltage across one of the circuit reactances when the circuit is resonated to the frequency of the impressed voltage. The ratio of the voltage across the reactance to the impressed voltage is the Q of the circuit. If the impressed voltage is constant, the voltmeter may be calibrated directly in Q, and, if most of the circuit losses occur in the coil, the Q measured in this way will be very closely the Q of the coil.

This method of measuring Q has been employed in the Q-Meter because it is simple and accurate and requires only a single operation — resonating the circuit — to measure Q.

The Q-Meter contains (1) an r.f. oscillator, (2) a measuring circuit consisting of main and vernier tuning condensers which tune the external coil to be measured, (3) a vacuum tube voltmeter of special design which reads the voltage developed across the tuning condenser and (4) a means for introducing a known amount of the oscillator voltage in series in the measuring circuit.

The procedure in measuring Q consists of either adjusting the oscillator to a predetermined frequency and tuning the circuit under measurement to resonance, or conversely of tuning the circuit with a predetermined capacitance and adjusting the oscillator to resonance. At resonance, the voltmeter indicates directly the Q of the circuit.

USES

The instruction book which accompanies each Q-Meter describes in detail the many applications of this instrument. A few of the more common uses are as follows:

R.F. Coils: The Q of all types of coils commonly used in radio frequency circuits may be determined by simply connecting the coil to the terminals provided, resonating this coil to the oscillator frequency and observing the Q as indicated on the Q voltmeter. The effective inductance of the coil may be determined directly from the decade inductance scale on the dial of the Q tuning condenser. Coils may be rapidly matched and Q simultaneously observed.

A.F. Coils: The Q and inductance of large inductance coils such as are used in supersonic and AF circuits (down to 1 kilocycle) may be measured. For this purpose provision has been made whereby the output of an external oscillator (1 kilocycle to 50 kilocycles) may be coupled into the oscillator transmission line within the Q-Meter. The same procedure as used with r.f. coils is employed.

Variable Condensers — Small Fixed Condensers: By substituting the condenser under observation for a part of the capacitance of the Q tuning condenser, the effect of the test condenser upon the circuit is directly indicated in terms of a loss in Q. By a simple computation the Q (or the power factor) of the test condenser may be determined. The change in setting of the Q tuning condenser is a direct measure of the capacitance of the condenser under test.

Insulating Materials — Dielectrics: For the measurement of insulating materials, a specimen Condenser is made by securing conducting surfaces on opposite sides of a plate of the material. The same technique used in measuring fixed condensers is employed.

Antennae: The effective series resistance, capacitance, inductance and fundamental frequencies of small antennae may be determined over a wide frequency range.

SPECIFICATIONS

Oscillator Frequency Range: Continuously variable from 50 kilocycles to 75 megacycles in eight self-contained ranges. (In conjunction with an external oscillator the frequency range of the Type 160-A Q-Meter may be extended from 50 kilocycles to 1 kilocycle for coil measurements.

Oscillator Frequency Accuracy: Generally better than ±1%, except the 50-75 megacycle range which is approximately ±3%.

Range of Q Measurements: The Q voltmeter is calibrated directly in Q, 20-250. The "Multiply Q By" meter, which measures the oscillator voltage injected in the Q measuring circuit, is calibrated in tenths from x1 to x2 and also at x2.5. The reading of the Q voltmeter scale is to be multiplied by the setting of the "Multiply Q By" meter. Hence, the total range of circuit Q measurements is from 20 to 625. Condensers, dielectrics, etc., which are measured by placing these in parallel with the measuring circuit, may have Q's as high as 5000.

Accuracy of Q Measurements: The accuracy of the direct reading measurement of circuit Q (for Q voltmeter readings between Q=50 and Q=250) is approximately 5% for all frequencies up to the region of 30 megacycles, and decreases with increasing frequency. Correction may be made for the error above 30 megacycles as it is principally a frequency effect. The accuracy of the measurement of condensers, dielectrics, etc. is generally better than 10% for Q's below 5,000 and up to 30 megacycles.

Capacitance Calibration Range: Main Tuning condenser 30-450 mmf., calibrated in 1 mmf. divisions from 30 to 100 mmf, and in 5 mmf divisions from 100 to 450 mmf. Vernier condenser, plus 3 mmf, zero, minus 3 mmf, calibrated in 0.1 mmf divisions.

Accuracy of Capacitance Calibration: Main tuning condenser, generally better than 1% or 1 mmf, whichever is the greater. Vernier tuning condenser ±0.1 mmf. The internal inductance of the tuning condenser at the binding posts is approximately .015 μhy.

Voltmeter: The Q Voltmeter is also calibrated in volts. A specially calibrated tube, type BRC 105A tube, is used.

Power Supply: 105-120 volts, 50-60 cycles. Also 210-240 volts, 50-60 cycles. Power consumption 50 watts.

Tubes: The instrument is supplied complete with the following tubes:

1 Type BRC 102-A*
1 Type BRC 105-A*
1 Type 5W4
1 Mazda 41

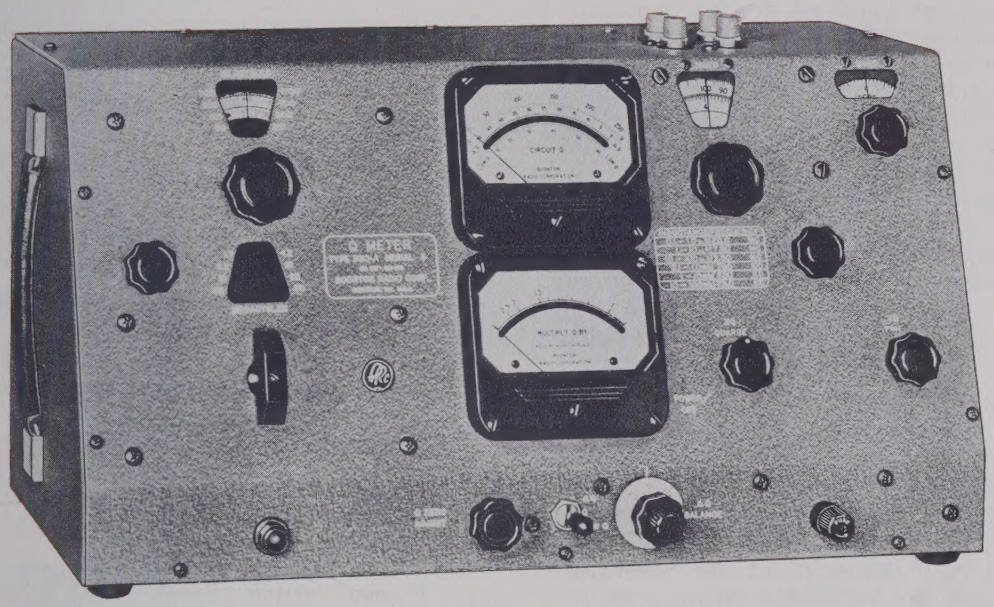
**Specially selected.*

Dimensions: Height 12.5", length 20", depth 8.5".

Weight: 25 lbs.

Q METER TYPE 260-A

FSN 6625-537-5699



Frequency Range 50 KC to 50 MC

Description

The Q Meter was first designed and introduced in 1934 as a means of measuring the Q or "Figure of Merit" of coils. Improved models and broadened applications have kept pace with a rapidly growing industry, and the Q Meter is recognized as a flexible general purpose device with a large number of uses. The Q Meter consists of a self-contained, continuously variable, stable oscillator, whose controlled and measured output is applied in series with a series-tuned, resonant circuit. A vacuum tube voltmeter with high output impedance is connected across the internal variable capacitor portion of the tuned circuit to measure the reactive voltage in terms of circuit Q. The coil portion of the tuned circuit is connected externally and represents the unknown to be measured. By inserting low impedances in series with the coil or high impedances in parallel with the capacitor, the parameters of unknown circuits or components can be measured in terms of their effect on the circuit Q and resonant frequency. Because of the high quality components used in the manufacture of the Q Meter, coupled with a design engineered to minimize unwanted inherent residuals, the instrument is extremely sensitive.

Features

As a result of our studies, field information and suggestions received from our custsomers, we have incorporated in our present Q Meters those modifications and additions which it was felt would increase the usefulness of the instrument.

1. "Lo Q" Scale. Direct reading expanded scale permits the measurement of Q down to 10.
2. "△ Q Scale." Also direct reading expanded scale to permit the reading of very small changes in Q resulting from the variation of test circuit parameters.
3. Thermocouple Protection. The Type 260-A utilizes a rugged thermocouple operating at 1/2 rated power, and the output of the oscillator is adjusted at the factory to avoid overload. Both of these features guard against accidental thermocouple overload.

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4. Power Supply Regulation. Through the use of an internal regulating transformer and an electronically regulated power supply, the operation of the instruments is not affected by normal power line voltage fluctuations.

5. Teflon insulation has been provided for the terminals of the 260-A, providing mechanical stability and low electrical loss. The oscillator output is controlled by varying the screen grid voltage of the oscillator tube to obtain smooth operation as well as good waveshape. A 0.02 ohm annular insertion resistor is used to improve Q meter accuracy. Provision is made for the use of an external oscillator to supply the Q Meter through a matching transformer (Type 564-A) to provide operation below 50 kc. down to 1000 cycles per second. A scale is also provided to read inductance directly at selected frequencies.

6. Meter scales with mirror reflectors are used to eliminate error due to parallax.

7. The instrument has been designed to minimize internal residual inductance and resistance.

8. The thermocouple as well as all tubes can be replaced by the customer without returning the instrument to the factory.

Uses

Coils: Circuit Q is read directly from a parallax-free meter. From the measurements made on coils, the distributed capacitance, effective inductance, and self-resonant frequency can be determined.

Capacitors: Capacitance from 0.1 pf to 100 K pf, and Q from 10 to 10,000 can be evaluated from measurements made on the Q Meter with and without the component connected. The self-resonant frequency of capacitors can be determined within the range of the instrument.

Resistors: The effective rf resistance, inductance or capacitance, and Q of resistors over a wide range can be determined.

IF and RF Transformers: Measurements can be made of effective impedance, Q, coefficient of coupling, mutual inductance, and frequency response.

Dielectrics: The Q Meters measure dielectric constant and dissipation factor, power factor, etc., of various grades of insulating materials and ceramics, including very low loss types. Samples with foils applied can be measured in a Hartshorn-Ward type of holder, or mounted directly on the Q Meter using a simple flat ground plate and connecting clip. Liquids held in a suitable container can also be measured.

Miscellaneous: The resistance, reactance, Q, and impedance of miscellaneous passive circuits, networks, filters, etc., can be determined with dc bias voltages applied if desired. Measurements can be made of antennas and coupling networks. Transmission line parameters necessary to compute characteristic impedance, attenuation, and velocity of propagation can be evaluated.

Specifications

Radio Frequency Characteristics

RF RANGE:
Total Range: 50 Kc. to 50 Mc.
1 Kc. to 50 Kc.*
*With external oscillator
No. Bands: 8

Band Ranges:

50 — 120 Kc.	1.7 — 4. Mc.
120 — 300 Kc.	4.2 — 10 Mc.
300 — 700 Kc.	10 — 23 Mc.
700 — 1700 Kc.	23 — 50 Mc.

RF ACCURACY: ±1% approximately.
RF CALIBRATION: Increments of approximately 1%.

Q Measurement Characteristics

Q RANGE: Total Range: 10 to 625
Low Range: 10 to 60
△ Range: 0 to 50

Q ACCURACY: ±5%* 50 Kc. to 30 Mc.
±10%* 30 Mc. to 50 Mc.
*For circuit Q of 250 read directly on indicating meter.

Q CALIBRATION:
Main Scale: Increments of 5 from 40 to 250
Low Scale: Increments of 1 from 10 to 60
△ Scale: Increments of 1 from 0 to 50
XQ Scale: Increments of 0.1 from 1 to 1.5
Increments of 0.5 from 1.5 to 2.5

Inductance Measurement Characteristics

L RANGE:
0.09 μh to 130 mh (effective inductance).*
*Direct reading at six specific frequencies.
L ACCURACY: ±3%*
*For resonating capacitance >100 pf and inductance >5μh.

Resolating Capacitor Characteristics

CAPACITOR RANGE:
Main: 30 to 460 pf
Vernier: —3.0 to +3.0 pf
CAPACITOR ACCURACY:
Main: ±1% or 1 pf whichever is greater
Vernier: ±0.1 pf
CAPACITOR CALIBRATION:
Main: 1 pf increments 30 to 100 pf
5 pf increments 100 to 460 pf
Vernier: 0.1 pf increments

Accessories

FURNISHED: None
AVAILABLE: Type 103-A Inductors
Type 513/518A Q Standards
Type 564-A Coupling Unit

Tube Complement

1 — OA2	1 — 5763
1 — OB2	1 — 6X4
	1 — 535-A

Mechanical Characteristics

MOUNTING: Sloping front cabinet, for bench use.
FINISH: Gray wrinkle, engraved panel (Other finishes available on special order).
DIMENSIONS: Height: 12-1/2" (31.7 cm)
Width: 20" (50.8 cm)
Depth: 8-1/2" (21.6 cm)
WEIGHT:
Net: 40 lbs. (18 kg); Gross Export: 98 lbs. (44.2 kg); Gross Domestic: 55 lbs. (24.8 kg); Legal Export: 50 lbs. (22.7 kg).

Power Requirements

260-A: 95-130 Volts, 60 Cps, 65 Watts
260-AP: 95-130 Volts, 50 Cps., 65 Watts

Price: 260-A: $990.00 260-AP: $990.00

Q-STANDARDS TYPES 513-A & 518-A

0.5 MC-1.5 MC
Type 513-A

1.5 MC-4.5 MC
Type 518-A3

5 MC-15 MC
Type 518-A2

15 MC-45 MC
Type 518-A1

50 KC-150 KC
Type 518-A5

150 KC-450 KC
Type 518-A4

Type 513-A

The Q-Standard Type 513-A is a shielded reference inductor which has accurately-measured and highly-stable inductance and Q characteristics. Specifically designed for use with Q-Meters Type 260-A and 160-A, the Q-Standard is particularly useful as a check on the overall operation and accuracy of these instruments, as well as for providing precisely-known supplementary Q-circuit inductance desirable for many impedance measurements by the parallel method. The Q-Standard consists of a specially-designed, high-Q coil of Litz wire, wound on a low-loss Steatite form. The coil is hermetically sealed inside a copper shield can which is filled with an inert gas under pressure. The desired Q-versus-frequency characteristics are provided by a carbon film resistor shunted across the coil. Two replaceable banana plug connectors mounted on the base serve to connect the unit to the Q-meter circuit. The Q-Standard is supplied in a convenient wooden carrying and storage case. Each unit is individually calibrated and marked with its true inductance (L), distributed capacity (C_d), and effective Q (Q_e) and indicated Q (Q_i) at 0.5, 1.0 and 1.5 mc, respectively. Tolerance: L ±1%—C_d ±2%—Q_e ±3% measured at 73°F. Q_i is an average Q-Meter reading. Any instrument deviating more than ±7% from the marked value is not operating in accordance with original specifications.

Nominal Values for Type 513-A

L - 250 μh		Cd - 8 pf	
	0.5 mc	1.0 mc	1.5 mc
Q_e	190	250	220
Q_i	183	234	200

Actual values of all these quantities are marked on the name plate of the Q-Standard.

With the unit in the Q-circuit, approximate resonant frequencies of 500, 1000 and 1500 kc are obtained with tuning capacitance of 400, 100 and 50pf, respectively.

Temperature Coefficients:

L and C_d — Negligible

Q_e — freq.	%△Qeff/°F
0.5 mc	—0.128
1.0	—0.083
1.5	—0.042

Overall Q-Standard Dimensions:
3″ (7.6 cm) diam. x 4-1/2″ (11.4 cm) h. (approx.)
Net Weight (including case): 28 oz. (1 kg) (approx.)

Price: Type 513-A: $97.00 ea.

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Types 518-A1 to 518-A5

Supplementing the Q-Standard Type 513-A, BRC has designed five additional Q-Standards Type 518-A. Similar in construction and performance to the 513-A, these Standards, in conjunction with the 513-A, provide frequency coverage from 50 KC to 50 MC — the entire range of Q-Meter Type 260-A. The units are useful as precision inductors and as a fast, convenient method for checking the overall operating accuracy of Q Meters.

Each model is supplied in a convenient wooden carrying and storage case and is individually calibrated and marked with its indicated Q and resonating capacitance (C) at each of three (3) discrete frequency points.

"Indicated Q" is an average Q-Meter reading — any instrument deviating from the marked value by more than ±8% from 50 KC to 30 MC, increasing to ±13% at 50 MC, is not operating in accordance with original specifications. Resonating capacitance accuracy: ±0.5% ±0.5 pf.

	518-A1	518-A2	518-A3	518-A4	518-A5
INDUCTANCE	0.25 μh	2.5 μh	25 uh	2.5 mh	25 mh
Low Freq. Data:					
Frequency	15 MC	5 MC	1.5 MC	150 KC	50 KC
Resonating C	420 pf	395 pf	440 pf	440 pf	400 pf
Indicated Q	175	195	175	170	90
Middle Freq. Data:					
Frequency	30 MC	10 MC	3 MC	300 KC	100 KC
Resonating C	100 pf	95 pf	105 pf	100 pf	85 pf
Indicated Q	235	235	225	180	130
High Freq. Data:					
Frequency	45 MC	15 MC	4.5 MC	450 KC	150 KC
Resonating C	40 pf	40 pf	45 pf	40 pf	35 pf
Indicated Q	225	205	230	135	125

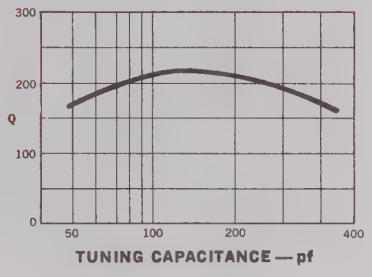
(Table shows nominal values)

Price: Type 518-A: $97.00 ea.

Set of five Type 518-A and one 513-A: $525.00

INDUCTORS TYPES 103-A & 590-A

'E 103-A



Illustrating construction, also relationship between Q and tuning capacitance for typical inductor

These inductors are designed specifically for use in the Q circuit of the Type 160-A and 260-A Q-Meters, for measuring the radio-frequency characteristics of capacitors, including materials, resistors, etc.

Type	Inductance	Approx. resonant frequency for tuning capacitance of: 400pf	100pf	50pf	Approx. Q	Capacitance pf
103-A1	1 μh	8	16	20 mc	180	6
103-A2	2.5 μh	5	10	14 mc	200	6
103-A5	5 μh	3.5	7	10 mc	200	6
103-A11	10 μh	2.5	5	7 mc	200	6
103-A12	25 μh	1.5	3	4.5mc	200	6
103-A15	50 μh	1.1	2.2	3 mc	200	6
103-A21	100 μh	800	1600	2000 kc	200	6
103-A22	250 μh	500	1000	1400 kc	200	6
103-A25	500 μh	350	700	1000 kc	170	7
103-A31	1 mh	250	500	700 kc	170	7
103-A32	2.5 mh	150	300	450 kc	170	8
103-A35	5 mh	110	220	300 kc	160	8
103-A41	10 mh	80	160	200 kc	140	9
103-A42	25 mh	50	100	140 kc	110	9
		100 pf		35 pf		
103-A50	0.5 μh	20 mc		35 mc	225	5.5
103-A51	0.25 μh	30 mc		50 mc	225	5.5
103-A52	0.1 μh	45 mc		75 mc	225	3.5

Each Type 103-A Inductor consists of a high Q coil mounted in a convenient shield and provided with plug terminals which plug directly into the coil terminals of the Q-Meter to facilitate the quick interchange of inductors for measurements at various frequencies.

Complete shielding eliminates errors in measurement due to coupling between the inductor and the test component and again with nearby objects, which coupling might alter the Q circuit constants during a measurement. Perfect shielding provides the desired stability.

The Q of the majority of the Type 103-A Inductors is in the region of 200, over the normal range of tuning capacitance of from 50 to 400 pico-farads. The approximate variation in Q with tuning capacitance of a typical 103-A Inductor is shown in the above curve. A few of the higher inductance inductors have a Q of less than 200. The approximate Q of each inductor is listed.

The true inductance of types A1 through A42 is adjusted to within 2 per cent of their nominal value. Tolerance on other coils is slightly wider. The total distributed capacitance varies as indicated.

For convenience in selecting the correct inductance, the approximate frequencies at which each inductor resonates with two or three different tuning capacitances is included in the list at the left.

Price: $17.75 each. Set of 16 Inductors for 260-A: $255.00 Set of 17 Inductors for 160-A: $270.00

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TYPE 590-A

Price: $17.75 each.

$95.00 for complete set of six.

Inductors Type 590-A are designed specifically for use in the Q Circuit of the Q Meters Type 170-A and 190-A for measuring the radio-frequency characteristics of condensers, resistors, and insulating materials. They have general usefulness as reference coils and may also be used for periodic checks to indicate any considerable change in the performance of the Q Meters.

Each inductor Type 590-A consists of a high Q coil mounted in a shield and is provided with spade lugs for connection to the coil terminals of the Q Meters. The shield is connected to the lugs which connect to the Low Coil terminal in order to minimize any changes in characteristics caused by stray couplings to elements or to ground.

Type	Inductance μh	Capacitance pf	Approximate Resonant Freq. mc.	Approximate Q	Approximate Distributed C pf
590-A1	0.05	95.0 — 7.5	70 — 230	350	1.5
590-A2	0.1	95.0 — 7.5	50 — 160	320	1.7
590-A3	0.25	100 — 7.5	30 — 100	380	2.3
590-A4	0.5	80 — 7.5	25 — 70	360	2.3
590-A5	1.0	60.0 — 7.5	20 — 50	350	2.9
590-A6	2.5	15.0 — 8.0	20 — 30	330	2.9

SECTION II

PERFORMANCE TESTING

Table II-1. Comparison of 260A and 160A Markings

260A Panel Engraving and Text Designation	160A Marking
XQ COARSE	None (Item 1, See page 38)
XQ FINE	None (Item 29, See page 38) NOTE: Not included on early 160A's
Q ZERO ADJUST	None (Item 20, See page 38)
CIRCUIT Q METER	Q
MULTIPLY Q BY	MULTIPLY Q BY

Table II-2. Equipment Required for Performance Testing

Instrument	Model	Required For	Ref. Para.	Required Characteristics
Audio Oscillator	-hp- 200CD	Capacitor Check	B3	20 KC at 5 V RMS
Q-Standards	BRC 513A or 518A Series	Voltmeter Check Q Check	B4	Accurate Q_i
Standard Variable Capacitor *	Gen'l Radio 1722 DP	Capacitor Calibration	C2	35-115pf ± 0.03% or ± 0.01pf 100- 600pf ±0.03% or ± 0.1 pf
Shielded Inductor	BRC 103A-32	Capacitor Calibration	C2	Shielded 2.5 mh Q approx. 170
Q Meter	BRC 260A	Capacitor Calibration	C2	Oscillator and resonance indicator
Crystal Calibrator or Electronic Counter with Amplifier and plug in	Ferris 33 -hp- 5245 L -hp-461A -hp-5251A	Frequency Calibration	C1	50 KC to 75 mc, accuracy better than 0.01% preamplifier for 20 mv RMS sensitivity of counter Only needed for 160A

*Depending on testing accuracy required, substitution may be made. Refer to Paragraph C-2 on page 15 for details.

SECTION II

PERFORMANCE TESTING

The following performance check is intended as an in-cabinet check of the 260A and 160A Q Meters to verify proper performance. Access to internal test points is not necessary as part of the procedure. The tests can be used for incoming quality control and routine preventive maintenance checks.

Subsection B gives preliminary checks as an indication of the operation of the instrument.

Subsection C presents procedures for testing specified accuracies of the Q Meter.

The following procedures refer to controls and front panel engraving on the 260A Q Meter. For equivalent markins on the 160A, refer to Table II-1.

A. EQUIPMENT REQUIRED

Test equipment used in the performance testing of the 260A and 160A Q Meters is given in Table II-2. This table lists the type of equipment to be used, the critical specifications required for testing, and recommended commercially available test equipment.

B. GENERAL OPERATION CHECKS

Instrument should be ON and in operation a few minutes.

1. Zero Controls

   (a) Short HI and GND posts together

   (b) On the 260A only : Adjust Q ZERO ADJUST for no movements of the CIRCUIT Q Meter when the front panel lever switch is alternately depressed and released from the LOW Q position.

   (c) The meter should read zero, exactly, if the meter mechanical zero is correct.

   On the 160A: Omit (b) and (c). Instead, adjust zero knob (item 20, page 38) for a zero reading on the Q Meter.

2. Oscillator - To see that the RF oscillator is oscillating and has sufficient output over its entire frequency range, proceed as follows:

   (a) Place the oscillator range on 50-120 KC. (50-150 KC on the 160A). Rotate XQ FINE control fully clockwise. (Early 160A's did not have a fine control).

(b) Advance the XQ COARSE control until the MULTIPLY Q BY Meter indicates 2.0. Rotate the frequency control through the entire range of the band and set the frequency to that point in the band where the MULTIPLY Q BY deflection is least.

NOTE: The performance of the Q Meter is not specified beyond the band edges as defined by the panel engraving (260A) or printing on the fiducial (160A), even though calibration marks may extend beyond the band limits.

(c) Advance the XQ COARSE control slowly and check that it is possible to get a MULTIPLY Q BY deflection at least X 1.0.

(d) Rotate the XQ COARSE control fully counter-clockwise (without actuating the power switch) before changing ranges. This is a normal operating precaution to prevent thermocouple damage.

(e) Repeat (b), (c), and (d) on each frequency range.

3. Resonating Capacitor Check - To determine that no obvious malfunction, such as shorted capacitor plates, exists at some particular dial setting, proceed as follows:

(a) Connect an audio oscillator (-hp- 200CD or equivalent) between the HI and GND posts. Set the frequency to approximately 20 KC, output voltage for near full deflection on the CIRCUIT Q Meter.

(b) Rotate the main Q capacitor and vernier capacitor through their entire range. A shorted plate would cause the meter indication to drop to zero.

(c) Remove audio oscillator.

4. Q Voltmeter - To check the voltmeter functions, proceed as follows:

(a) Connect a 513A, 518A-3, A4, or A5, Q Standard across the COIL terminals and, using normal Q Meter techniques, see that the coil resonates.

Omit steps (b), (c), and (d) for the 160A.

(b) With a resonance peak, as indicated on the CIRCUIT Q Meter, adjust the XQ COARSE and XQ FINE controls for a CIRCUIT Q Meter reading of 60. Check peak. Depress the lever key to the LOW Q position. Repeak. Note that the CIRCUIT Q Meter now indicates 60 on the LOW Q scale. (Meter tracking inaccuracies will normally prevent an indication of exactly 60).

(c) Adjust the XQ controls for a MULTIPLY Q BY indication near 1.0. Raise the lever key to the ΔQ position and adjust the ΔQ BALANCE controls for a CIRCUIT Q Meter indication of zero on the ΔQ scale. The scale on the skirt of the ΔQ COARSE control should approximately agree with the CIRCUIT Q reading when the lever key is released.

(d) Check for smooth meter operation when the ΔQ BALANCE controls are varied.

C. TESTING SPECIFIED ACCURACIES

1. Oscillator Frequency

(a) Connect a crystal calibrator between the LO and GND terminals (20 mv is available when XQ = 1.0). Maintain the MULTIPLY Q BY Meter deflection within a few percent of 1.0 since there is a slight shift of oscillator frequency at other XQ settings.

(b) Check frequency at convenient increments across each frequency range.

SPECIFICATIONS: ± 1% of the dial setting (260A)
± 2% of the dial setting below 50 mc and
± 5% of the dial setting above 50 mc (160A)

NOTE: More than 1/2 VRMS is available at the 160A phone jack on the cabinet top or at the 260A thermocouple block by installing a BNC Tee (remove the access door). However, ANY connection will seriously affect the frequency calibration at the higher frequencies.

Frequency calibration with an electronic counter connected to the oscillator output should be restricted to frequencies below 1 mc. Above this frequency, connection should be made only between LO and GND posts. An amplifier, such as the -hp- 461A may be used as a preamplifier for an electronic counter.

2. Resonating Capacitor

The internal resonating capacitor, Items 19 and 20 on the 160A schematic (page 39) or C201 in the 260A, is used to adjust the capacitance across the circuit under test to resonate it at the measurement frequency.

The calibration method described in this Manual is based on substitution of a known amount of capacitance from a precision capacitor for an indicated amount of capacitance in the Q Meter, using a resonant circuit and a second Q Meter as an indicator. Calibration is done at a relatively low frequency with respect to the operating range of the instrument in order to prevent stray inductance effects.

To avoid repetition, the complete procedure including the adjustment technique will be found in Section III D "Resonating Capacitor Adjustments".

Where only a check on the resonating capacitance calibration is desired, the 513A or 518A series Q-Standards may be used. The capacitance required to resonate the 513A may be calculated from nameplate information. (For details refer to APPENDIX C, page 5 of BRC Notebook #1 or the Applications Instructions for Q-Standard Type 513A) The nameplate information on the 518A series Q-Standards includes the resonating capacitance required for three frequencies. The values given are accurate to ± 0.5% or ± 0.5 pf, whichever is greater. The frequency of the oscillator should set accurately with an external standard to eliminate frequency error.

3. Circuit Q Measurement Accuracy

The specified accuracy of the 260A is ± 5% to 30 mc, ± 10% from 30 mc to 50 mc for a circuit Q of 250 read directly on the indicating meter (when XQ = 1.0.) Circuit Q is the indicated Q on the 260A which includes the measuring circuit losses as well as the effects of the residual circuit parameters. (These are completely discussed in the 260A Manual).

The 160A accuracy is specified as approximately ± 5% for all frequencies up to the region of 30 mc for circuit Q values between 50 and 250 (when XQ = 1.0).

Boonton manufactures Q-Standards for the purpose of checking the overall performance of BRC Q Meters. The nameplate on the standards gives the indicated Q (Q_i) for the coil when measured on a properly functioning Q Meter. A data sheet containing Q-Standard information is included in Section I of this manual. Additional information may be found in Appendix A where a "Note on Q-Standards" is reprinted from an NBS publication.

For the purpose of verifying the accuracy of Q readings, it should be sufficient for the 260A to indicate the Q-Standard indicated Q (Q_i) within ± 7% when using the Type 513A Inductor, or ± 8% with the 518A types (± 13% above 30 mc). Set the MULTIPLY Q BY Meter to 1.0 for these checks.

Allow a warm-up time of 1/2 hour or more for the 160A, 2-1/2 hours or more for the 260A.

Corrections must be applied to the 160A Q readings when using the 518A type coils. Refer to BRC Notebook number 8 or the Application Instructions accompanying a 518A coil. No corrections are required when the 513A Q-Standard is used.

The number of Q-Standards to be used for verifying Q-Meter performance and accuracy will depend upon the users requirements. Where there is no need for extensive checking through the entire frequency range, two Q-Standards, the 513A and 518A-1, are the recommended minimum for normal overall performance checks.

Refer to Section III, H1 and 2 for details of their application.

FACTOR FOR Q DATA FOR USE WITH Q METER
FOR 160-A

OF RESONATING CAPACITANCE

		400 MMF	200 MMF	40
	15 MC	0.96	0.96	1.15
42	5 MC - 15 MC	0.95	0.98	1.0
43	1.5 MC - 4.5 MC	1.00	1.00	1.0
	KC	0.99	0.97	0.95
45	50 KC - 150 KC	0.97	0.90	0.8

SECTION III

TEST AND CALIBRATION

Table III-1. Equipment Required for Test and Calibration

Instrument	Model	Required For	Ref. Para.	Required Characteristics
Crystal Calibrator or Electronic Counter with Plug In and Amplifier	Ferris 33 -hp-5245L -hp-5251A -hp-461A	Frequency Calibration	B2	50 KC to 75 MC Accuracy better than 0.01% (To extend range to 75 mc for 160A calibration) preamplifier for 20 mv RMS Sensitivity
Shielded Inductor	BRC103A-32	Capacitor Calibration	D1	Shielded 2.f mh Q ≈170
Q Meter	BRC 260A	Capacitor Calibration Q Circuit ΔQ Check	D1 F2	Oscillator and Resonance Indicator
Standard Variable Capacitor	Gen'l Radio 1422 DP	Capacitor Calibration	D1	35-115 pf 0.03% or ±0.01 pf 100-> 600 pf ± .03% or 0.1 pf (with special calibration chart)
Shielded Inductor	103A-22	Backlash Check Q Circuit ΔQ Check	C1 F2	250 μh shielded Q ≈ 200
Shielded Inductor	103A-51	RF Contact Resistance	C2	0.25 μh shielded, Q ≈ 225
Audio Oscillator	-hp-200CD	Voltmeter Calibration	E1	10 V RMS at 100 KC
Precision Attenuator	Gertsch RT-10 RatioTran	Voltmeter Calibration	E1	Accurate Division to 0.2 V
2 ea. 1 μfd, 200 V W DC Low Loss Capacitors	-hp- Part 0170-0073	Voltmeter Calibration	E1	1.0 μf ± 10% 200 W V DC Polystyrene dielectric
Q Standards	BRC 513A or 518A series	Overall performance	H1	Accurate Q_i
VTVM	-hp-400H -hp-400L	Signal Injection Calibration	G2	Calibrate at measurement frequency with -hp-738A, 739A

SECTION III

TEST AND CALIBRATION

A. EQUIPMENT REQUIRED

Test equipment used in the test and calibration of the 260A and 160A Q Meters is given in Table III-1. This table lists the type of equipment to be used, the critical specifications required for testing, and commercially available test equipment.

B. OSCILLATOR ADJUSTMENTS

1. Mechanical

(a) When the tuning capacitor plates are at the full mesh stop, the line on the upper half of the fiducial should coincide with the end line below the low frequency ranges The line on the lower half of the fiducial should coincide with the end line below the low end of the high frequency ranges.

(b) Check for free operation of the friction drive and that no contact is made with the fiducial.

(c) The range switch contact clips and both sets of shorting arm contact clips should be checked to make certain that each of the two sides of each clip deflect outward when coil cradle contact pin entry is made on each range. Only the tip of the clip should contact the pins.

(d) Oxidized contacts usually cause erratic MULTIPLY Q BY meter indications. It is recommended that the contacts be cleaned with fine abrasive and lubricated with BEACON 325 grease (an Esso product) or equivalent.

2a. Frequency Calibration (260A)

The general conditions outlined in Section II, paragraph C-1 apply.

Each frequency range has two calibration adjustments; a threaded magnetic core to calibrate the low frequency of the range, and a trimmer capacitor to set the high frequency end. An additional trimmer, C129, is shunted across the oscillator tube to compensate for tube variations when replacement becomes necessary. C129 is normally set to mid range before a complete calibration is made.

Usually a small readjustment of C129 is all that is necessary after replacing the oscillator tube.

The coils for the eight ranges are wound on four coil forms mounted in cradles on a turret, each coil form being used for two ranges. The threaded magnetic cores to adjust coil inductance are turned into each end of the form and fastened with Q-MAX when the oscillator is tested at the factory. Because of the physical arrangement of the coils, four bands cannot be conveniently adjusted without removing the oscillator assembly from the front panel. This exposes the cores and allows them to be loosened with acetone so adjustment can be made. CAUTION: Do not use GLYPTAL Thinner to loosen the cores. Coils (and corresponding cores) are identified on the end frame of the turret by the letters "B" (for back) and "F" (for front) with the band number. The high end adjusting capacitors are also identified by numbers.

Table III-2 shows the range, band number and location on the turret

Table III-2. 260A Oscillator Coil Location

Band	Freq Range	Coil Location
1	50-120 KC	Front
2	120-300 KC	Front
3	300-700 KC	Back
4	700-1700 KC	Front
5	1.7 - 4.2 MC	Back
6	4.2 - 10 MC	Front
7	10 - 23 MC	Back
8	23 - 50 MC	Back

To provide for tracking adjustment, the outer rotor plates of the tuning capacitors are slotted. Any adjustment required should be minor. For tracking of the 10-23 MC and 23-53 MC ranges, adjust the 13 plate section. For ranges 300-700 KC, 700-1700 KC, 1.7 - 4.2 MC, 4.2 - 10 MC, adjust the 25 plate section. It is suggested that tracking be done on bands 4 and 8. Small readjustments may be necessary to bring the other bands within specifications.

2b. Frequency Calibration (160A)

The general conditions outlined in Section II, Paragraph C-1 apply.

The oscillator is a tuned-grid, tickler feedback circuit. There are no metallic cores or trimmer capacitors on all the coils to make the necessary adjustments for frequency calibration. Adjustment is made by changing coil locations or turns.

In general, the removal of grid turns from the coil group lowers the self inductance of the grid coil and its distributed capacitance. The total effect is to raise the frequency for a given setting of the dial, with a greater change occuring at the lower frequency end of the band.

Removal of plate turns, or an increase in plate to grid coil spacing decreases the mutual inductance between the plate and grid windings and the frequency will be raised for a given dial setting. The change will be more pronounced at the high frequency end of the band.

Refer to Table III-3 for a convenient guide to 160A frequency adjustments. The table gives the necessary adjustments to RAISE the frequency for a given capacitor setting. The opposite adjustments are made to lower the frequency.

Metallic flaps are provided on both sections of the oscillator tuning capacitor. Their adjustment will affect the minimum capacitance and consequently the high frequency end of the ranges.

The outer rotor plates of the oscillator tuning capacitor are slotted to provide minor adjustments of the frequency dial tracking. Any adjustment necessary should not allow rotor to stator spacing of less than 0.008".

The oscillator output voltage is adjusted by changing the output coil position on each range except the 25-50 mc range, where a loop inside the coil form is adjusted. There is no adjustment on the 50-75 mc range. On any range, the frequency and output voltage adjustments interact. Thus, if any adjustments are made, both frequency calibration and output voltage must be checked.

NOTE: Some of the frequency ranges have dial calibrations extending beyond the limits shown on the fiducials. The specifications do not apply to the portions of the dial marking beyond the limits marked on the fiducials.

SPECIFICATIONS:

Frequency - ± 2% below 50 mc, ± 5% above 50 mc.

Output Voltage - Sufficient to produce a MULTIPLY Q BY meter deflection of at least 1.0 at all frequencies.

Table III-3. A Convenient Guide to 160A Frequency Adjustments

Frequency Range and Band Number	Adjustment Necessary to RAISE the Frequency for a Given Tuning Capacitor Setting	
	GRID COIL General shift at all frequencies slightly more at the low end of band	PLATE COIL Pronounced change at high end of band
50-150 KC 1	Remove Turns	Remove Turns
150-450 KC 2	Remove Turns	Plate turns cannot be removed. Instead, mutual inductance is lowered by pushing grid coil toward end of plate coil.
450-1500 KC 3	Shift turns from large section over to section having fewer turns	Push plate winding off grid winding
1.5 - 4.5 MC 4		
4.5 - 12 mc 5		
12 - 25 mc 6	Same as Band 3 - 5	Push plate wire crossing inside of tube toward cradle side of coil form. This tends to make the half turns double back on the outside turns and reduces its self inductance
25 - 50 mc 7	Push grid wire crossing away from cradle side of coil form. This tends to make the half turn double back on the outside turns.	Spread part of an outside turn slightly.
50 - 75 mc 8	No Adjustment	No Adjustment

C. RESONATING CAPACITOR CHECKS

Before calibration of the resonating capacitor is begun, it is suggested that backlash and RF contact resistance be checked. Repair work may alter the calibration.

1. Backlash

(a) Connect a 103A-22 Inductor (or equivalent) to the COIL terminals. Set the frequency range to 300-700 KC (260A) or 450-1500 KC (160A), and the resonating capacitor vernier at zero.

(b) Approach 450 pf on the main capacitor dial from a CCW direction and stop at 450 pf with no overshoot. Resonate the coil with the frequency dial (coarse tuning) and vernier capacitor (fine tuning). Note vernier reading.

(c) Approach 450 pf from the opposite direction, stopping at 450 pf with no overshoot. Re-resonate with the vernier capacitor only. Subtract readings.

(d) If backlash (ΔC) is greater than .7 pf there is mechanical trouble in the resonating capacitor.

(e) Check backlash at 250 pf for less than 0.4 pf and also at 70 pf for less than 0.3 pf, changing the oscillator frequency to establish resonance as in 1 (b) above.

2. RF Contact Resistance

RF Contact Resistance at the ends of the rotor shaft or at the disc and fingers connected to the top plate will cause erratic Q readings and interfere with establishing a resonance peak. To check for this condition, proceed as follows.

(a) Connect a 103A-51 coil (or equivalent) to the COIL terminals.

(b) Set the resonating capacitor to 100 pf, the frequency to the 23-50 mc range (25-50 mc on the 160A) and resonate the coil with the frequency dial.

(c) Set the MULTIPLY Q BY reading to 1.1. Detune the circuit to the low C side and using the main C dial friction drive, retune slowly. Note the Q reading.

(d) Offset to the high C side and again retune, noting the Q reading.

(e) The readings noted in (c) and (d) should be equal. The retuning from an off resonance condition should result in a smooth rise in Q reading.

(f) Repeat at 200 pf and 400 pf using the 10-23 mc oscillator range (12-25 mc on the 160A) for these settings.

D. RESONATING CAPACITOR CALIBRATION AND ADJUSTMENT

In the following procedure the Q Meter to be calibrated will be referred to as No.1, the indicator 260A as No.2. (The 160A Q Meter is not recommended as the indicator because of the difficulty in obtaining adequate definition of the peak of resonance in the procedure.)

1. Vernier Capacitor Calibration

The vernier capacitor is difficult to adjust because of its precise accuracy specification. The calibration technique differs from the recommended adjusting technique so they are treated separately. Calibration is made with reference to the 0.0 pf dial reading. The adjustment starts with the -3.0 pf dial reading as a reference. To calibrate the vernier proceed as follows:

(a) Refer to Figure III-1 for physical placement of the units. Turn on No.2. (No.1 remains OFF) Connect a 103A-32 coil to the No. 2 coil terminal. Connect LOW range of the precision capacitor to the HI and GND terminals of No. 2 through a short piece of coaxial cable. Set the internal capacitor of No. 2 to minimum capacitance.

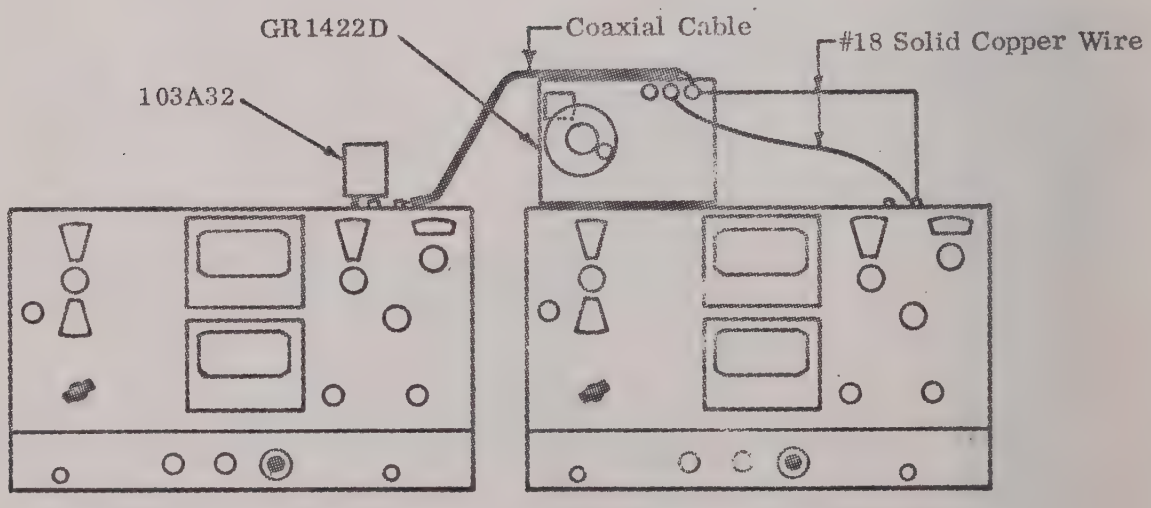


FIGURE III-1. Equipment Setup

(b) Connect the ground and low range terminals of the precision capacitor to the GND and HI CAP terminals, respectively, of Q Meter No.1. (HI COND terminals if No.1 is a 160A)

(c) Set the precision capacitor to a convenient point in its range (100.00 pf, for example). Call this dial reading D_o. Set the vernier capacitor of No.1 to 0.0 pf.

(d) Resonate the coil with the frequency dial of Q Meter No.2 (coarse) and the vernier capacitor (fine). Raise the lever key and adjust the ΔQ BALANCE controls for an on-scale indication on the CIRCUIT Q Meter. Repeak the circuit with the lever switch in the ΔQ position. This method increases the sensitivity of the indicator 5 times and allows more accurate adjustment of resonance. The XQ reading need not be maintained at X1.0 but can be somewhat lower.

(e) Adjust the vernier of No.1 to -1.0 pf and re-resonate with the precision capacitor, lifting the lever switch to the ΔQ position to refine the peak. Record the precision capacitor dial reading as D_{-1}.

(f) Calculate ΔC in the following manner. Consult the calibration chart supplied by the manufacturer of the precision capacitor, calling e_o the correction at D_o, e_{-1}, the correction at D_{-1}. Then

$$C_o = D_o + e_o, \quad C_{-1} = D_{-1} + e_{-1}$$

where C_o and C_{-1} are the corrected capacitances at dial readings D_o and D_{-1} respectively.

Then $C_{-1} - C_o = \Delta C$, the change in capacity, which should be 1.0 pf ± 0.1 pf.

(g) Set the vernier of No.1 to -2.0 pf and re-resonate with the precision capacitor, calling the dial reading of the precision capacitor D_{-2}. Calculate $C_{-2} - C_o$ which should be 2.0 pf ± 0.1 pf.

(h) Continue the calibration of -3.0, +1.0, +2.0 pf.

2. Vernier Capacitor Adjustment

The same equipment setup in the preceding section is used, except the vernier to be adjusted is set at -3.0 pf and the precision capacitor corrections are not used.

(a) Set the precision capacitor to a convenient reading (100.00, for example). Set the vernier of No.1 to -3.0 pf and resonate the circuit with frequency (coarse) and No.2 vernier (fine).

(b) Remove exactly 1.0 pf from the precision capacitor dial. (The time required to make the adjustments can be minimized by not using the dial corrections and adjusting the vernier plates as accurately as possible in the following steps.)

(c) Resonate with No.1 vernier. If the vernier dial does not read -2.0 very closely, bend plates as necessary, checking the reference at -3.0 pf as often as it is found necessary.

(d) Remove another 1.0 pf from the precisision capacitor and repeak with No.1 vernier, which should read -1.0 pf and -1.0 pf. If not, bend plates to bring the resonance as close to -1.0 as possible.

(e) Recheck -3.0 pf reference and -2.0 pf and -1.0 pf readings again. Bending of the slotted sections can affect the previous adjustments slightly.

(f) Continue adjusting the other cardinal points on the vernier. Try to keep the dial errors on one side.

(g) Now calibrate the vernier capacitor by following section 1A above.

3. Main Capacitor Calibration and Adjustment

(a) Connect the equipment as in Section 1A (a) above. Connect a wire between the precision capacitor ground and Q Meter No.1 GND terminal.

(b) Suspend another No.18 AWG copper wire (solid) from the low range terminal on the precision capacitor to a point in air 3/8" above the HI CAP terminal on Q Meter No.1. The tip of this suspended lead must be straight, without hooks or loops, and must point down to the terminal. Isolate this lead from surrounding objects.

(c) Set the precision capacitor to the high end of the low range. Record the dial reading as D_0. Set the main capacitor of No.1 to 30.0 pf, approaching the point in a clockwise direction without overshoot. Set No.1 vernier capacitor to 0.0 pf.

(d) Resonate the circuit with Q Meter No.2 frequency (coarse) and vernier capacitor (fine). Use the ΔQ function to improve the peak as described in 1A (d) above.

(e) Touch the suspended wire to the HI CAP terminal with the least movement of the wire. Re-resonate the coil with the precision capacitor. Note the dial reading as D_1.

(f) Calculate the Q Meter capacitance at this setting: Determine the precision capacitor corrections, e_o for D_o, e_1 for D_1. Then $C_o = D_o + e_o$, $C_1 = D_1 + e_1$. The true capacitance corresponding to a dial reading of 30 pf is equal to $C_o - C_1 + 0.15$ pf. (The Q voltmeter adds 0.15 pf when the Q Meter is energized for normal operation.) If the capacitance is not 30 ± 1 pf, adjust the minimum C adjustment vane. (See Fig. III-2.)

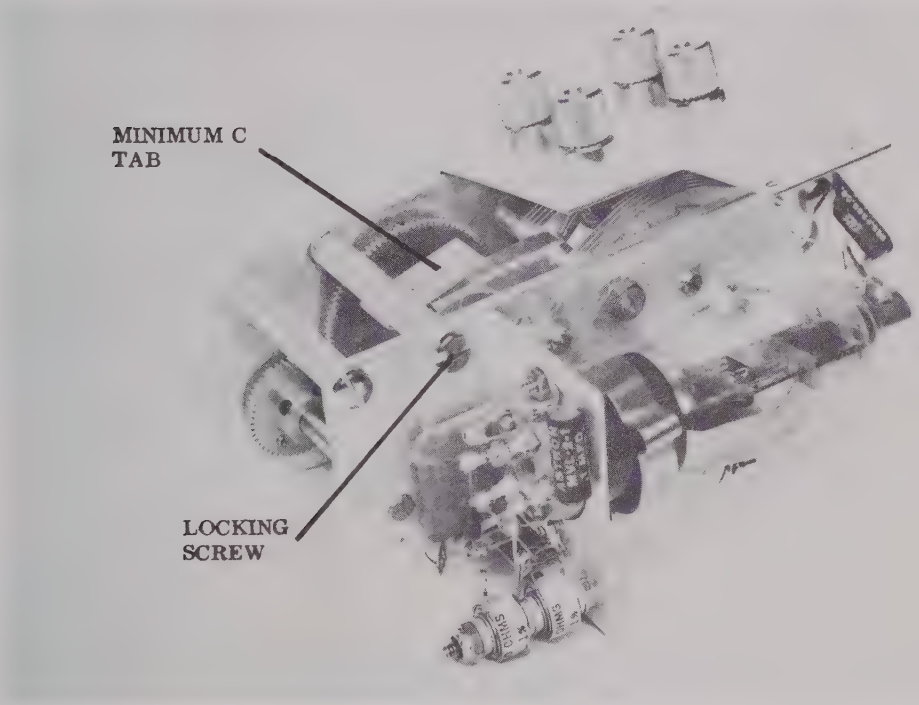


FIGURE III-2. Location of Minimum C Adjustment Vane

(g) Continue calibration at 40 and 60 pf, bending plates as necessary. Always set the dial from a clockwise direction to eliminate backlash. Note: A convenient calibration table can be drawn to make computations quickly. See Table III-4 for a sample calibration.

TABLE III-4 Sample Work Sheet for Capacitor Calibration

MMFD Dial	Precision Cap. Dial D	Correction e	Corrected C, pf	Difference from Ref.	+.015 = Actual C, pf
Ref	115.0 (D_o)	-.05 (e_o)	114.95		
30	84.82(D_1)	+.01 (e_1)	84.83	30.12	30.27
40	74.50	- .02	74.48	40.47	40.62
60	54.95	- .03	54.92	60.03	60.18
(etc)					

(h) The low range of the precision capacitor can be used to calibrate up to 80 pf on the dial so the high range must be used to continue the calibration. Switch the wires to the high range and set the precision capacitor or dial for at least 600 pf. Establish a resonance condition with No.1 HI CAP terminal disconnected as in step (b) above. Call the precision capacitor dial reading D_o again.

(i) Connect the suspended wire to the HI CAP terminal, set the main capacitor of No.1 to 100 pf (clockwise approach), and re-resonate with the precision capacitor.

(j) Continue the calibration at dial settings 150, 200, 300, 400, and 450 pf, adjusting the slotted rotor plates as necessary to meet the specifications of $\pm 1\%$ or ± 1 pf whichever is larger.

(k) Enter the reference and new dial readings on the previously prepared table to simplify computations.

E. Q VOLTMETER

1. General

The voltmeter circuit is adequately bypassed for the frequencies generated by the Q Meter. Because the frequency response falls off below 20 kc (7 kc on the 160A), calibration should be done above this frequency unless additional bypassing is temporarily added to the voltmeter circuit to extend the low frequency response.

The addition of 1 μfd capacitors from the Q voltmeter tube plate and cathode pins to ground will extend the low frequency response below 1 kc. Any accurate, variable, low distortion source of 1 kc can then be used for calibration. An -hp-200CD oscillator, -hp-400H VTVM (for monitoring the oscillator output), and a Gertsch RT-10 RATIOTRAN have been used successfully.

If bypassing is not added, it is necessary to use a higher frequency and a VTVM accurately calibrated at the frequency to be used (100 kc is recommended). The special calibration is required from 0.2 to 5V RMS for the 260A calibration, 1 to 5V RMS for the 160A.

The following general precautions should be taken when setting up the equipment:

The resonating capacitor should be at minimum C to reduce shunt loading of the source.

The external resistance across the HI and GND posts should be 3 megohms or less to reduce gas current effects in the voltmeter tube. (This precaution should be taken if substitute calibration equipment is used.)

Only one instrument should be grounded through the power attachment plug to eliminate ground loops.

2. Main Q Scale

(a) After 1/2 hour warmup, turn off the power and wait 2 minutes for the filter capacitors to discharge and the Q voltmeter tube cathode to cool. Adjust the meter movement mechanical zero. Turn power back on.

(b) Allow the Q Meter to return to stable operation.

On the 160A: With the power supply HI-LO switch on HI, oscillator at 1 mc and XQ at 1.0, adjust the electrical zero while shorting the HI and LO posts.

On the 260A: Short the HI and GND posts and adjust the Q ZERO ADJUST control for no deflection of the CIRCUIT Q meter when the front panel lever switch is alternately depressed and released. The meter should read exactly zero. Remove short.

(c) Apply 4.0 V RMS between HI and GND posts.

On the 160A: Adjust VTVM calibration control, item 31 (see 160A Mechanical Parts) for a reading of 200 exactly. (early 160A's did not have a calibration control. The voltmeter is checked to a tolerance of ± 5 Q.)

On the 260A: Adjust R310 for a reading of 200 exactly.

(d) Apply 5.0 V, 3.0 V, 2.0 V, and 1.0 V RMS successively and check meter tracking. The meter should read 250, 150, 100, and 50, respectively, within 2% of full scale (± 5 Q).

3. LO Q Scale (260A Only)

(a) Apply 1.0 V RMS between HI and GND posts. Adjust R308 for a LO Q reading of 50.

(b) Apply successively 1.2, 0.8, 0.6, 0.4, and 0.2 V. The meter should read 60, 40, 30, 20, and 10, respectively, ± 2.5% of full scale (± 1.5 Q on the LO Q scale).

4. ΔQ Scale (260A Only)

(a) Apply 3.0 V RMS between HI and GND terminals. Adjust ΔQ BALANCE controls for a ΔQ scale reading of 50.

(b) Increase input to 4.0 V. Adjust R306 for a ΔQ scale reading of 0 (full scale).

(c) Repeat (a) and (b) until no further adjustment is necessary.

(d) Check voltmeter linearity by applying 1.0 V, balancing the ΔQ BALANCE controls for a 50 reading (on the LO Q scale) and increasing the input to 2.0 V. The meter should deflect 49 divisions ± 2 on the ΔQ scale. (Give a reading of 1 ± 2 Q)

(e) Repeat (d) for 2.0 - 3.0 V and 4.0 - 5.0 V. The meter should deflect 50 divisions ± 2. (give a reading of 0 ± 2 Q)

(f) Apply 4.0 V and adjust ΔQ balance controls for full scale. The engraved skirt on the ΔQ BALANCE coarse knob should indicate 200. If not, loosen the setscrews and slip the knob as necessary.

F. OTHER VOLTMETER CHECKS

1. Q Voltmeter Grid Current

(a) Allow at least 1 hour warmup.

(b) Short the HI and GND terminals and electrically zero the Q Meter. Remove the short.

(c) The Q Meter should indicate less than 60 Q. If not, the Q Voltmeter tube has excessive grid current and should be replaced.

2. Q Circuit ΔQ

This check is principally a troubleshooting technique to verify that the external circuit under measurement is not shunted by losses in the terminals, resonating capacitor assembly, or voltmeter tube. It need not be made if the Q Meter agrees with Q Standard nameplate information, particularly at low resonating capacities and high Q readings.

(a) Place the Q Meter to be tested to the rear of another Q Meter, separated by 3" with both instruments facing the operator. Attach the coil to the front Q Meter. Apply power to both Q Meters.

(b) Interconnect the GND terminals of the two instruments. Suspend a length of solid #18 wire from the front Q Meter HI CAP terminal so the free end points directly down and is 1" removed from the HI CAP (HI COND on the 160A) terminal on the rear of Q Meter.

(c) Preset controls as follows

Front Q Meter: Frequency 1000 KC approx. Resonating capacitor 70 pf.

Rear Q Meter: (being tested)
Resonating capacitor set to 30 pf. (If the instrument is a 160A, also set the oscillator to 1200 KC, XQ= 1.2, this is to place normal load on the unregulated power supply).

(d) Resonate the coil with the frequency control of the front Q Meter. Measure the Q of the coil (call it Q_1). If the front Q Meter is a 260A, balance the ΔQ BALANCE for full scale ($\Delta Q = 0$).

(e) Connect the suspended wire to the HI terminal of the rear Q Meter. Re-resonate the circuit with the capacitor of the front Q Meter, calling the Q reading Q_2. Determine $Q_1 - Q_2$ (or ΔQ). The amount of ΔQ indicates the additional losses introduced into the Q measurement by the connection of the second Q circuit. ΔQ's in excess of 15 should be investigated by repeating the measurement with the power off and the Q voltmeter tube grid connection removed. If the new ΔQ is significantly lower than before, the voltmeter tube should be replaced. If not, major circuit losses occur in the terminal post insulation, Q capacitor stator insulators or in the grid resistor of the voltmeter tube.

G. SIGNAL INJECTION SYSTEM

1. General

The BRC 260A and 160A Q Meters use the resonant rise method of Q measurement, where, if $Q \geq 10$, $\frac{E}{e} = Q$ (See Appendix B and C). E is the voltage measured by the Q voltmeter (5 V full scale) and e is the voltage developed across the injection resistor in the thermocouple assembly.

In the 260A, approximately 1 amp flows through the thermocouple at XQ = 1.0, developing 20 MV across an annular (low inductance) 0.02 Ω resistor. In the 160A, approximately 0.5 amp flows through a 0.04 Ω strip resistor when XQ = 1.0.

To minimize errors in the injection system, it is necessary to consider the thermocouple and MULTIPLY Q BY meter as a matched combination. The calibration and scale tracking tolerances on the meter movement and the shape of the thermocouple output vs input current characteristics all combine to form poor calibration accuracy unless the two components are matched. For this reason, it is necessary to furnish the instrument serial number when ordering replacement thermocouples or XQ meters. A replacement can then be selected and calibrated to match the original as closely as possible. Ultimate accuracy would be achieved by returning the meter to the factory when ordering a thermocouple so the two can be checked together.

The calibration of the injection system may be done in the field with an accurately calibrated -hp- 400H or 400L VTVM. The Q Meter oscillator provides the power to the thermocouple. A frequency is chosen where low oscillator distortion reduces the waveform errors in the calibration.

The factory calibration method uses DC to power the thermocouple and DC standard meters to measure the characteristics of the thermocouple assembly. The resultant accuracy is better than the method suggested above, but involves the use of costly instruments that may not be readily available for field calibration.

2. Calibration

(a) Allow 2-1/2 hours of warmup for the 260A. The injection resistor has a positive temperature coefficient, requiring calibration at operating temperature.

Allow 1/2 hour warmup for the 160A. The injection resistor temperature coefficient is very low - the time is required for oscillator stabilization.

(b) Set the oscillator to the low end of band 2 or 3. (120 KC or 300 KC on the 160A, 150 KC or 450 KC on the 260A). Connect the VTVM between the LO and GND posts. Avoid ground loops through the power line.

(c) Increase oscillator output until XQ meter indicates 1.0. The VTVM should read 20.0 MV ± 1%, not including frequency and scale errors in the VTVM.

If the injection voltage is not correct, adjust the value of the calibrating resistors on the 260A thermocouple assembly (only one is used on the 160A - connected at the XQ meter terminal).

A + 1 Ω change in calibrating resistance results in a + 1/2% change in injection voltage, approximately.

The calibrating resistors in the 260A form part of an RF filter network. it is advisable to keep the difference between them less than 5 Ω. The resistor values should always be more than 10 Ω.

Note: The 260A should be allowed to return to operating temperature after the cabinet is opened to effect a resistor change.

(d) Check the XQ meter linearity by reducing the oscillator output until the meter reads X2.0. The VTVM should read 10.0 MV ± 4% (260A) or ± 5% (160A). If the error is greater, (not including VTVM errors) the meter and thermocouple are no longer matched.

(e) If necessary, check the injection at XQ readings of 1.2, 1.5, and 2.5. The millivolt readings should be 16.67 ± 3%
13.33 ± 3%
and 8.00 ± 6% (260A)
or ± 7% (160A), respectively.

(all tolerances do not include VTVM errors)

H. OVERALL PERFORMANCE USING Q STANDARDS

1. General

The Q of standard inductors should be measured on the Q meter. Details have already been presented in Section II C-3 (page 16). The readings may also be checked using the ΔC technique. For further details consult BRC Notebook 4.

2. Troubleshooting

Six Q-Standards are available from BRC. Two of these will provide for normal overall checking. (The types 513A and 518A-1) One coil checks the low frequency performance around 1 MC, the other the high frequency performance to 45 mc. These two coils are very effective troubleshooting aids as illustrated by Table III-5.

Table III-5. Troubleshooting Chart using 513A and 518A-1 Q Standards

Allow a warmup period of 1/2 hour for 160A, 2-1/2 hours for 260A

Trouble Indication			Possible Cause
General increase in Q indications (compared with Q Standard label date) as frequency is increased.			Thermocouple assembly injection resistor has become inductive
Indicated Q is higher with higher XQ settings			Q voltmeter tube non-linearity
Measurements taken with 513A Q-Standard (Qi tolerance ± 7% of value on label)			
0.5 mc high Qi low Qi	1.0 mc high Qi low Qi	1.5 mc high Qi low Qi	XQ or Q voltmeter calibration
Qi in spec	Qi in spec	low Qi	Q voltmeter tube input conductance too high. (shows up at low C setting because tank impedance is high.)
Qi in spec	low Qi	Qi in spec	On 260A only. Suspect Q Voltmeter tube (High Q reading with a high Z tank impedance shows grid circuit clipping)
Measurements taken with 518A-1 Q Standard: (Qi tolerance ± 8% up to 30 mc, ± 13% mc to 50 mc)			
15 mc high Qi low Qi	30 mc high Qi low Qi	45 mc high Qi low Qi	XQ or Q voltmeter calibration
low Qi	Qi in spec	Qi in spec	Worn or tarnished terminals, dirt in Q capacitor or poor plate spacing. (There are high circulating currents at high C settings)
Qi in spec	Qi in spec	low Qi	Insulation losses, contamination of insulators, dirt in Q capacitor, Q voltmeter tube.
Qi in spec	low Qi	Qi in spec	On 260A only. Suspect Q voltmeter tube (with Q≈249 signal voltage is near maximum. Clipping in grid circuit shows up.)

518A-1 nameplate data must be corrected when used with a 160A. Refer to "Application Instructions for the Q Standard Type 518A" supplied with the 518 series Q standards.

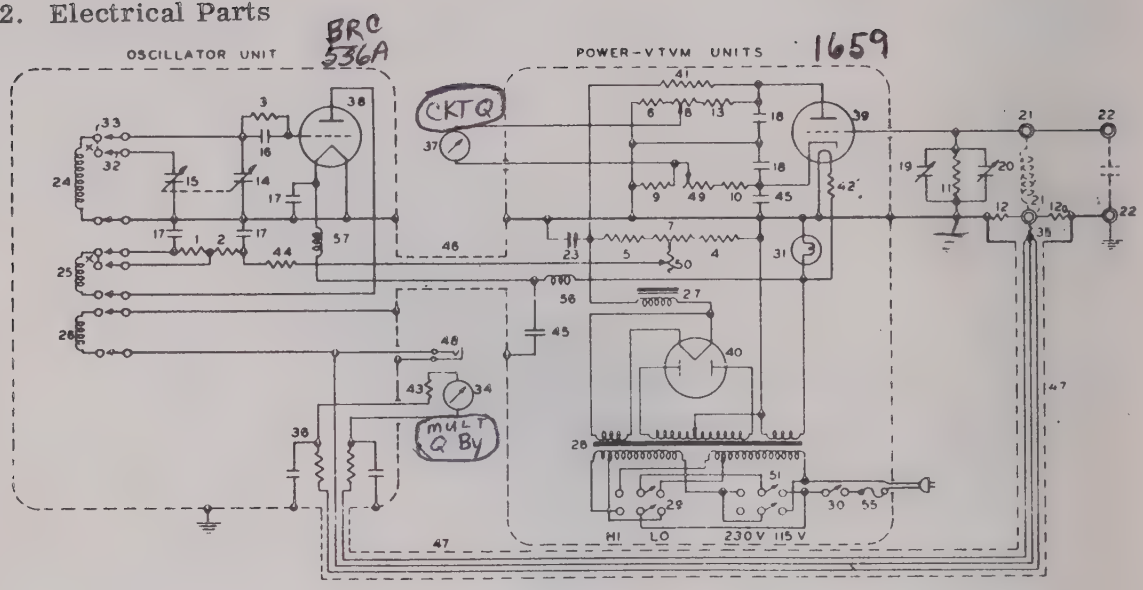
SECTION IV

PARTS IDENTIFICATION

AND

SCHEMATICS

2. Electrical Parts



160A Schematic

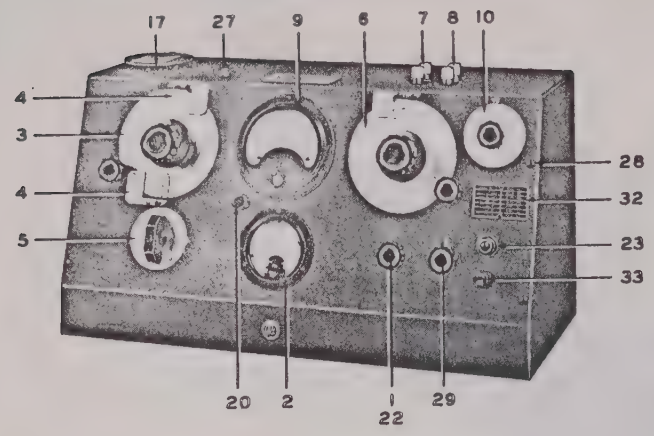
Item	Description	Part Number
1	Resistor, fixed, WW, 1 K Ω ± 5%, 4W	BRC 80145
2	Resistor, fixed, WW, 200 Ω ± 5%, 10 W	BRC 80107
3	Resistor, fixed, comp., 82 K Ω ± 5%, 2W (two in parallel) replaces original 40 K	-hp- 0692-8235
4	Resistor, fixed, WW, 2.4 K Ω ± 5%, 10 W	BRC 80286
5	Resistor, fixed, WW, 750 Ω ± 5%, 10 W	BRC 80140
6	Resistor, fixed, WW, 200 Ω ± 5%, 1W	BRC 80103
7	Resistor, var., WW, 8 K Ω 50 W with switch	BRC 81335
8	Resistor, var., WW, 200 Ω ± 10%, 2W	-hp- 2100-0844
9	Resistor, fixed, comp., 24 K Ω ± 5%, 1W	-hp-0689 -2435
10	Resistor, fixed, WW, 22 K Ω ± 1%, 1/2 W	-hp- 0811-0292
11	Resistor, fixed, film, 100 M Ω ± 15%, 1W	-hp- 0732-0001
12,12a	Resistor, fixed, part of thermocouple	not separately replaceable
13	Resistor, fixed, comp., 27 K Ω ± 5%, 2W	-hp- 0692-2735, 2 in parallel
14,15	Capacitor, var., air (Oscillator Tuning)	BRC 84701
16	Capacitor, fixed, mica, 100 pf ± 5%	-hp- 0160-0789
17	Capacitor, fixed, mica, 3000 pf ± 5%	BRC 82321
18	Capacitor, fixed, mica, 5100 pf ± 5%	BRC 82333
19,20	Capacitor, var., air, special	BRC 84067
21,22	See mechanical parts, Items 7, 8	
23	Capacitor, fixed, electrolytic, 3 X 10 μf/450V	-hp- 0180-0250

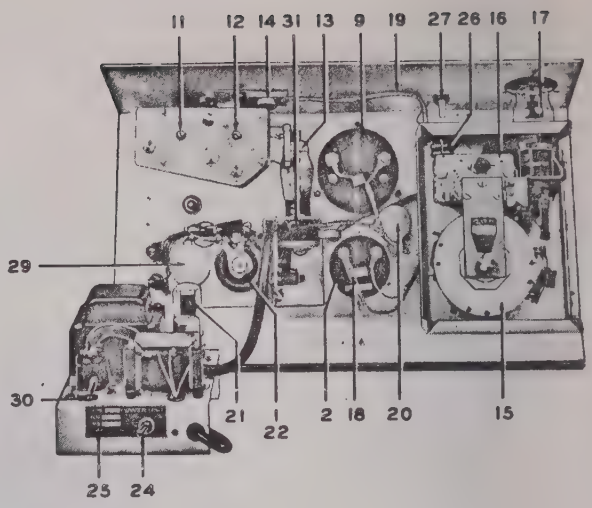
Item	Description	Part Number
24,25,26	Oscillator Coils	
27	Choke, filter, 10h, 80 ma/dc	-hp- 9110-0094
28	Transformer, power	BRC 85006
29	Switch, toggle, DPDT	-hp- 3101-0005
30	Switch, part of item 7	
31	Lamp, incandescent, #47	-hp- 2140-0009
32	Contacts, switch, oscillator range (3 types used)	BRC 60067 short BRC 60137 long BRC 302019 bent
33	Turret assembly, oscillator	
34	Meter, MULTIPLY Q BY	BRC 92015R - exchange only Supply serial of 160A
35	Thermocouple Assembly	BRC 165A - supply serial of 160A
36	Filter Assembly, consisting of: 2 ea. Resistor, fixed, WW, 20 Ω ± 2%, 1/2 W 2 ea. Capacitor, fixed, mica, 1000 pf ± 5%	 BRC 80016 -hp-0140-0018
37	Meter, CIRCUIT Q	BRC 92012R - exchange only
38	Tube, oscillator	BRC 536A - selected 45, (was BRC 102A)
39	Tube, Q Voltmeter	BRC 535B - selected 1659 (535A may be used also)
40	Tube, rectifier, 5Y3	-hp- 1930-0010
41	Resistor, fixed, comp., 1 K Ω ± 5%, 1W	-hp-0689-1025
42	Resistor, fixed, WW, 0.3 Ω special	BRC 80709
43	Resistor, fixed, WW, value selected at factory	BRC 80015, included with type 165A thermocouple assy. *
44	Resistor, fixed, WW, 100 Ω ± 5%, 1W	BRC 80064
45	Capacitor, fixed, paper, 0.1 μf, 400V	BRC 83001
46,47	Cable, shielded	part of thermocouple assy.
48	Jack, phone, single circuit	BRC 89038
49	Resistor, variable, WW, 3 K Ω ± 10%, 4W	-hp- 2100-0848
50	Resistor, variable, WW, 1 K Ω ± 5%, 4W	BRC 81109
51	Switch, same as item 29	
55	Fuse, 1-1/2 amp, 3AG	BRC 93250
56	Choke assembly, rf, special	BRC 60929
57	Choke, 1.07 μh, special	BRC 300098

* 80015 is the BRC part number for a family of resistors. The ohmic value must also be specified. Values are available from 8 Ω to 63 Ω.

A. 160A

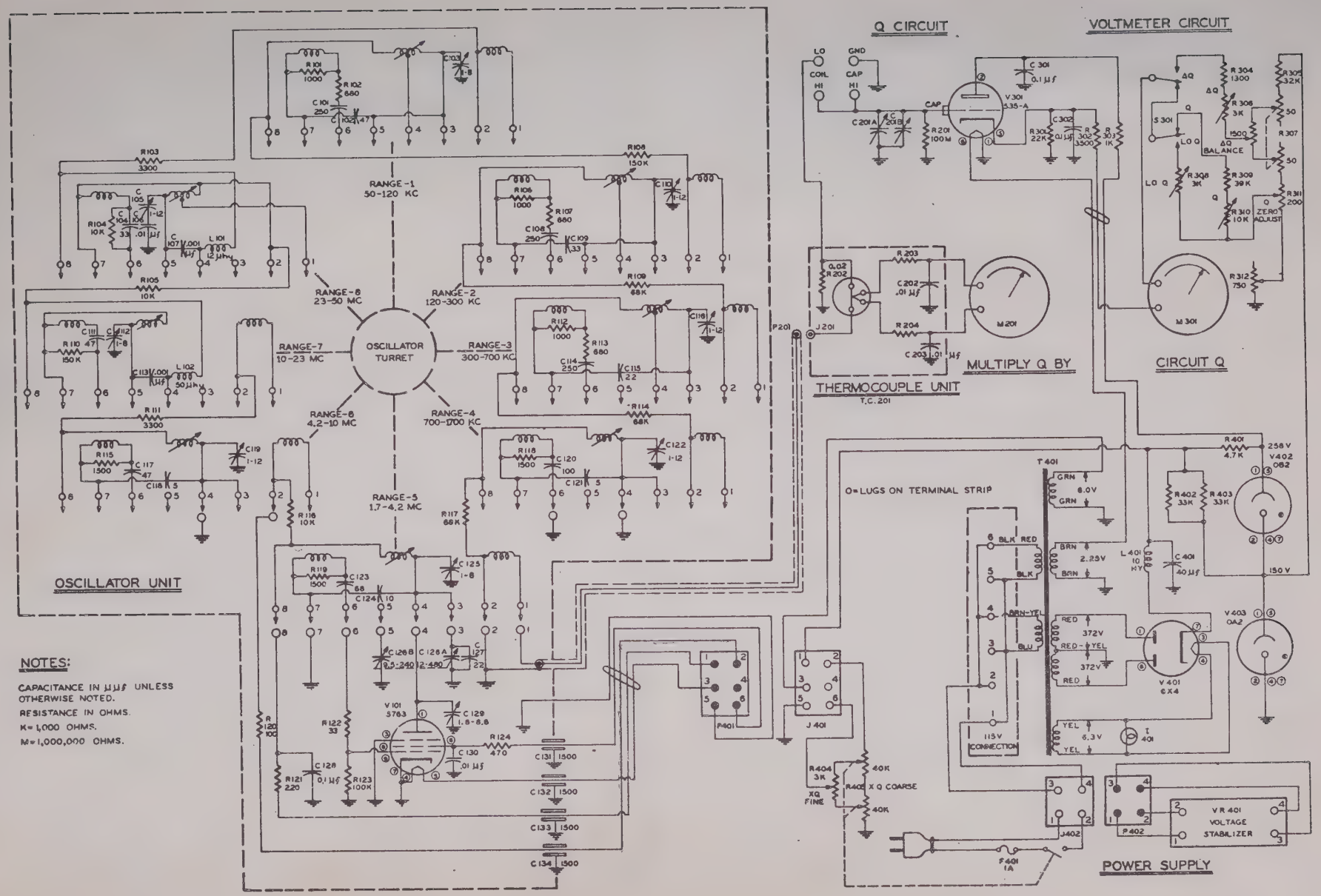
1. Mechanical Parts





Item	Description	BRC Part No.	
1	Knob	300648	
2	Meter, MULTIPLY Q BY	92015R	exchange only
3	Frequency Dial & Knob Assy.	60077	
4	Fiducial (KC)	60005	
	Fiducial (MC)	60006	
5	Range Switch Knob Assy.	60076	
6	Capacitor Dial & Knob Assy.	60132	
	(L-C Dial conversion kit for early 160A's)	560A	
7,8	Terminal nut	60081	
	complete binding post Assy.	60086	
9	Meter, circuit Q	92012R	exchange only
10	Vernier Capacitor Dial & Knob Assy.	60075	
11,12	Q Capacitor	84067	
13	Q Voltmeter Tube	535B	selected
14	Thermocouple	165A *	
15	Oscillator Turret	301107	
16	Oscillator Tuning Capacitor	84701	
17	Oscillator Tube	536A	selected 45
18,19		part of thermocouple	
20	VTVM Zero Adjust Knob	87003	
21	Rectivier	5Y3	
22	ON/OFF Switch, part of Output Control	not separately available	
23	Pilot Lamp, #47	90904	(-hp-2140-0009)
24	HI-LO Toggle Switch	88059	
26	Thermocouple Filter Unit	60065	
27	Jack	98038	
29	Output Vernier Knob	87002	
30	115/230 Switch	88059	
31	VTVM Calibration Control	81210	
32	Frequency Reference Plate	93726	
	Vernier Knobs (2)	87003	
	Vernier Disc Assy	301422	
	Fiducial for Q Capacitor	60722	

* Serial number of 160A required when ordering replacements.


OSCILLATOR UNIT
OSCILLATOR TURRET
RANGE-1 50-120 KC
RANGE-2 120-300 KC
RANGE-3 300-700 KC
RANGE-4 700-1700 KC
RANGE-5 1.7-4.2 MC
RANGE-6 4.2-10 MC
RANGE-7 10-23 MC
RANGE-8 23-50 MC
Q CIRCUIT
VOLTMETER CIRCUIT
THERMOCOUPLE UNIT
T.C. 201
MULTIPLY Q BY
CIRCUIT Q
POWER SUPPLY
VOLTAGE STABILIZER
O=LUGS ON TERMINAL STRIP
NOTES:
CAPACITANCE IN µµf UNLESS OTHERWISE NOTED.
RESISTANCE IN OHMS.
K=1,000 OHMS.
M=1,000,000 OHMS.

SECTION V

APPENDIX

APPENDIX A. Note on Q Standards

Q standards are most frequently employed as a means of checking the performance of Q meters. They are inductors which, in some cases, have been shunted by a high resistance in order to achieve a broader Q vs frequency characteristic. Their values are determined, at the factory, with a Q meter which serves as a standard for all other instruments of that particular type. Q standards, in addition to serving as transfer standards for instrument comparison, may be used as supplementary inductors to increase the measurement capabilities of the Q meter. They also may be employed as "shelf" standards and used in conjunction with other circuitry for a wide variety of measurement applications.

The value of resonating capacitance and indicated Q for a coil, as given by the manufacturer is the value which should be observed on a properly functioning Q meter. However, the value given for indicated Q is the ratio of reactance to resistance of the entire circuit which includes the coil as well as the measuring circuit of the Q meter. On the other hand, the effective value of Q reported by NBS is the ratio of reactance to resistance of the coil in the absence of the measuring circuit of the Q Meter. The difference between indicated and effective value is caused by the residual parameters of the Q meter circuit and includes both series resistance and series inductance. Beginning at about 5 megacycles this difference becomes increasingly more pronounced as the frequency increases and may reach 100 percent in Q and 10 percent in resonating capacitance at 50 megacycles. If all of the residual characteristics of the Q meter circuit were known then it would be possible to correct the indicated value and arrive at the proper effective value. This, of course, would require extensive calibration of the Q meter.

In order to perform a complete calibration of a particular Q meter the instrument in question would have to be submitted along with a set of Q standards, so that the oscillator, the thermocouple circuit, the voltmeter, the insertion resistor, and the resonating capacitor could be calibrated. This would not only be expensive, but would provide NBS with a workload which it is not prepared to handle with presently existing facilities.

In the measurement of a complex impedance the real and imaginary parts are physically inseparable and hence each must be measured in the presence of the other. Therefore, all impedance measuring devices must measure impedance either in the form of $R \pm JX$ or $Z\angle\theta$ rather than R or X individually, and correspondingly the accuracy of the measurement must be in terms of the total impedance. In the case of a component which has a phase angle near either 0^{o} or 90^{o}, the major component will have nearly the same accuracy as that of the total impedance, but a simple analysis will show that the minor component may vary widely without appreciably affecting this accuracy. In the measurement of Q then, it may be said that for a given accuracy of total impedance, the accuracy to which Q may be determined decreases as Q increases. Other complications, such as contact resistance and the lack of a connector with a definable plane of reference, contribute still other uncertainties particularly at the higher frequencies. For these reasons, no statements of accuracy are given at present for NBS Q standard calibrations.

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SERVICE NOTE

P-00160-60001

STOCK NO. 00160-60001
(old No. BRC-60086)

BINDING POST ASSEMBLY

The binding post assembly, Stock No. 00160-60001 is a replacement assembly for all BRC model 160A Q Meters.

REPLACEMENT PROCEDURE

1. The Q Tuning unit is removed from the instrument. Facing the front of the Q unit find two screws (on the upper left edge that secure the top plate. Remove screws. Do not attempt to remove plate until the end flaps of the copper strap are unsoldered from their stator connections. Lift plate straight up so that silver contactors will not be disturbed in their alignment.

2. Place plate on its back with " contacts " pointed up. Use 1/2 wrench on the one nut securing mica to plate. Remove nut and washer. Then using a heavy soldering iron running quite hot, quickly unsolder strap from binding posts. Apply high heat for a short period so that protective coating on mica is not injured. Then with copper strip off drop mica from plate.

3. Leave plate in same position and insert new terminal plate. It is imperative that the untinned binding post be used to secure the mica to the top plate. The remaining binding posts are tinned and should occupy the relative positions shown in Figure #1.

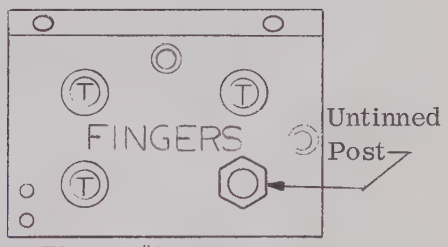

Figure #1

4. Solder copper strap across the two top posts that are pre-tinned for ease in doing this operation. At this point the capacitor is ready for re-assembly by reversing the foregoing procedure.

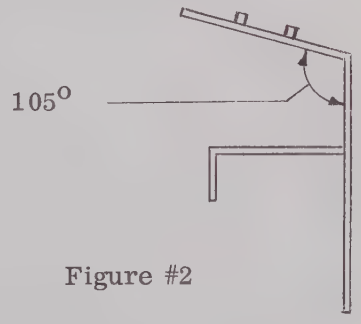

Figure #2

5. Special care should be taken so that the six silver fingers are in good contact with the disc on the capacitor rotor. An angle of 105 degrees should be maintained between front of capacitor and top plate as shown in Figure #2 above.

CAUTION: Do not handle mica with fingers. Use cotton gloves or tweezers.

BOONTON DIVISION

Hewlett-Packard Company

GREEN POND ROAD
ROCKAWAY, NEW JERSEY 07866

Precision Electronic Instruments since 1934

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SERVICE NOTE

P-165A

STOCK NUMBER 165A

THERMOCOUPLE ASSEMBLY

The thermocouple unit Stock No. 165A is a replacement for Boonton Radio Model 160A Q Meters. The thermocouple unit and associated calibrating resistor are calibrated at the factory for a particular Q Meter (indicated on the tag attached to the part) and should be installed only in that particular Q Meter.

The replacement thermocouple unit consists of:

(a) A shielded thermocouple mount
(b) An 0.04 ohm coupling resistor
(c) A thermocouple, and
(d) A shielded cable for connecting the thermocouple to the oscillator. Also included in the cable are the wires connecting the DC output from the thermocouple to the RF filter in the oscillator unit, and then to the MULTIPLY Q BY Meter.
(e) A guard plate, used for shipping, which protects the projecting thin tinned copper strip which connects to the Q Meter LO post.

REPLACEMENT PROCEDURE

1. Remove panel from Q Meter. Remove nine screws around sides and top edge of panel. Place panel face down, preferrably on some soft material.

2. Remove oscillator shield box cover. Remove four screws on top surface of cover. Loosen three screws on outside edge and loosen three hex-headed screws on inside edge of shield box cover. Slide cover off.

3. Disconnect defective thermocouple unit. Unsolder the three wires connected to the RF Filter and oscillator output terminals within the oscillator shield box (see "interior" view of type 160A Q Meter, Fig. 4, item 26 in Instruction Manual for Q Meter, Types 100A, 160A, and 170A. NOTE: In early editions of manual see Fig. 2, item 26). Unsolder the thin tinned copper strip (leading from the thermocouple unit to the adjacent binding post) at the binding post.

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CAUTION: Use a hot iron and supply heat only long enough to free the solder to avoid overheating and possible damage to the mica insulating, the binding post, and also to the .04 ohm coupling resistor within the thermocouple unit. Care must be exercised in lifting the thin tinned copper strip from the binding post to avoid damage to this and to the .04 ohm resistor.

4. Remove the thermocouple unit from the panel by removing the two screws which secure it. These screws are accessable from the top of the panel.

5. Remove the calibrating resistor (this is located at the "Multiply Q Meter", see item 18 "interior" view).

6. Install the replacement thermocouple unit. Remove the guard plate from the replacement thermocouple unit by carefully removing the protective cardboard piece and the 6/32 binding head screws which secure the guard to the thermocouple unit.

   Secure the thermocouple unit in place in the Q-Meter with the two screws mentioned in paragraph 4. Reverse the operations mentioned in paragraph 2 and 3, using the same precautions.

   CAUTION: In soldering the thin tinned copper strip of the replacement thermocouple unit to the binding post, it is important that a slight amount of slack be left in the strip. It is also important that no part of the strip touch the nut which secures the binding post.

   CAUTION: Check the connections for correct polarity of the TC output leads to the "Multiply-Q-By-Meter". If incorrectly connected, these leads may be reversed at the meter.

7. Install the new calibrating resistor. Replace panel on cabinet.

   The Q Meter is ready for operation. No calibration of the thermocouple is necessary.

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